AP Biology

Unit 3.2 – Cell Cycle & Heredity

Notes & Practice Quiz

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Section 1 – Cell Cycle Phases & Regulation

1.1 – What are the parts of the cell cycle?

The **cell cycle** is the series of events when a cell grows & reproduces itself by dividing. The phase of the cell cycle when the cell is not dividing is called **interphase**. There are 3 parts of interphase: G1, S & G2 phases. **G1 phase** is when the cell grows & performs any essential functions. The **S phase** is when DNA replicates ("S" for Synthesis of DNA). The **G2 phase** is when the cell makes final preparations for cell division such as duplicating organelles & making more proteins. Once interphase is complete, the cell enters the **M phase** which is when the DNA (chromosomes) will be separated and the cell itself will divide. Draw figure 12.6 of the cell cycle on p.231.

1.2 – When is the cell cycle regulated?

There are 3 checkpoints in the cell cycle: G1 checkpoint, G2 checkpoint & the M checkpoint. These checkpoints actually work through a feedback circuit: When levels of certain chemicals reach a set level, a response occurs. The two major molecules involved are called **cyclin-dependent kinases (cdk's)** and **cyclins**. Cyclin levels fluctuate constantly and as they increase, they bind & activate cdk's. Kinases are molecules that phosphorylate (energize) other molecules so it should not be a surprise that they cause actions during cell divisions like spindle fiber movements, chromosome alignments & cytoplasm division. For each process, there is a unique cyclin.

1.3 – How do the G1 & G2 checkpoints regulate cell division?

The **G1 checkpoint** is most crucial and usually progresses through the rest of the checkpoints if passed. If not passed, the cell will enter a non-dividing part of the cycle called G0 phase. Mature cells like red blood cells, muscle cells & nerve cells that do not regenerate are in this phase. The **G2 checkpoint** checks that DNA replication was accurate & complete. If not passed, the DNA will be repaired if possible or the cell will be destroyed.

1.4 – How does the M checkpoint regulate cell division?

The **M checkpoint** is crucial to proper cell division. This checkpoint assures proper chromosome alignment prior to separation during anaphase. As stated previously, the levels of cyclins & cdk's fluctuate and this phase is a good model to see that. As cyclin accumulates, a high enough level will trigger it to bind to cdk, forming a complex called **MPF**. MPF acts as a signal that the M-phase is proceeding accurately. Once continuing through the M-phase, MPF actually activates enzymes that will degrade the cyclin of the MPF complex, leaving only cdk behind. Draw figure 12.17 of these regulation events.

1.5 – How does cancer result from faulty regulation?

Cancer is any disorder in which cells divide uncontrollably due to their abnormal cell cycle signals. We also consider growths & tumors symptoms and this is the most basic observation of uncontrolled cell growth. Two models for why this occurs are based on overstimulation of the c ell cycle based on **oncogenes** & failure to inhibit the cell cycle based on mutated or missing genes. We will learn about some of these signaling pathways in unit 3.3 but draw figure 18.24 to get an idea of how overstimulation or under-inhibition can trigger cancer cells.

Section 2 – Cell Division Phases & Processes

2.1 – What are the differences among somatic cells & gametes?

All cells can be classified as either 1. **Somatic cells**: Regular body cells or 2. **Gametes**: Sperm or egg cells. Gametes each have 1 copy of every homologous chromosome, but somatic cells each have 2 copies of every homologous chromosome. These **homologous chromosomes** are those that have the same length & location of genes (called a **locus**) but the genes can be different allele forms since 1 is inherited from the mother and the other is inherited from the father. Somatic cells are usually able to divide to replace themselves when old or damaged and must divide so they are exactly the way they were. Gametes however carry diverse genetic information to the next generation during sexual reproduction. The M phase of the somatic cell cycle consists of **Mitosis** & **Cytokinesis** to produce 2 genetically identical daughter cells from 1 parent cell. The M phase of the gamete cell cycle consists of 2 rounds of **Meiosis** & **Cytokinesis** to produce 4 genetically varied daughter cells from 1 parent cell.

2.2 – How Are Mitosis & Meiosis similar & Different?

Both mitosis & meiosis begin their cell cycle with 1 cell. Each cell has 2 copies of every homologous chromosome, denoted as **2n** called **diploid** (double) where **n** is the **haploid** (single) number of homologous chromosomes in the cell. A human for example has 23 homologous chromosomes from their mother & 23 from their father for a total of 46. So our diploid 2n = 46. The S phase duplicates the DNA so then each homologous chromosome has an attached clone of itself, called a **sister chromatid**. Draw figure 13.4 on p.251. This diagram shows that the 2n = 6 meaning 3 homologous chromosomes came from each parent. Notice though that each chromosome has been duplicated so the actual amount of DNA in total at this point (prophase) is 12 instead of 6.

During mitosis the chromosomes condense during **prophase** but during **prophase 1** of meiosis 1, each homologous chromosome also pairs up with its other homologous chromosome in a **tetrad** pair. During their pairing time in prophase 1, **synapsis** and **crossing over** take place which result in the homologous pairs swapping some alleles.

During mitosis each homologous chromosome will line up in a single layer at the middle of the cell (**metaphase/equatorial plate**) in **metaphase** but in meiosis, **metaphase 1** lines up homologous chromosomes in a double-layer of pairs.

Mitosis undergoes 1 round of cell division that splits the sister chromatids & cell in **anaphase**, **telophase** & **cytokinesis** resulting in 2 cells with the same number of chromosomes as the original cell.

Meiosis undergoes 2 rounds of cell division that first separate homologous chromosome pairs in **anaphase 1** and then divides the cell in **telophase 1** & **cytokinesis 1**. Each homologous chromosome is then split into sister chromatids during **anaphase 2**, followed by each cell dividing during **telophase 2** & **cytokinesis 2**. This results in 4 cells with half the number of chromosomes and mostly different allele combinations than the original parent cell.

Draw figure 13.9 on p.256 that shows these major differences. Note on p.255 that the steps of meiosis 2 are identical to mitosis and that only way to differentiate a single cell in mitosis from meiosis 2 is if you can see that crossing over happened.

2.3 – How Are cell divisions different between plants & animals?

Eukaryote cells have complex motor proteins that separate their chromosomes during anaphase. Each chromosome has a non-coding region of DNA forming a constricted region called the

centromere. Bound to the centromere are proteins called **kinetochores** that degrade attached **spindle fibers**, making them shorten but giving the illusion that the fibers are "pulling" the chromatids apart. Animal cells lack cell walls and so their cells generally pinch off in the center by a **contractile ring** of proteins that contracts the cytoplasm & membrane until it is cleaved. Plant cell walls actually divide the cell by the Golgi secreting vesicles that form a centralized **cell plate**. The cell plate continues to grow until it completely separates the large plant cell into 2 plant cells.

Section 3 – Traditional Heredity Patterns

3.1 – How is the law of segregation modeled?

Draw figure 14.5 on p.267. Mendel discovered that when a **true-breeding** (homozygous) white flowered plant is crossed with a true -breeding (homozygous) purple plant, all of the offspring are purple. This demonstrated the **law of dominance**: simple traits come in 2 varieties, a dominant allele and a recessive allele. If the dominant allele is present, it will always be expressed over the recessive allele. His next step was to cross 2 of the F1 purple offspring and he found they were always in a 3:1 ratio or 75% dominant phenotype, 25% recessive phenotype. The fact that the recessive allele was able to "come back" led Mendel to believe that some mechanism segregated the parents' alleles for their traits before fertilization. Today we know that this process is meiosis and explains the **law of segregation**.

3.2 – Solving common genetics problems

First off in solving genetics problems, you must know the following terms: **phenotype, genotype, dominant allele, recessive allele, P-generation, F1 & F2 generations, heterozygous, homozygous, homozygous dominant & homozygous recessive**. Second, you should note the difference between phenotypic ratios and genotypic ratios, which are modeled in figure 14.6 on p.267. Finally, a **testcross** is useful for determining an unknown genotype. This is performed by crossing a homozygous recessive individual with an individual of unknown genotype. Copy the example in figure 14.7 on p. 267.

3.3 – How is the law of independent assortment modeled?

Mendel figured out the **law of independent assortment** for simple traits: assortment of alleles for one trait doesn't affect the assortment of alleles for a second (or third, etc.) trait. He concluded this by performing a 2-trait cross for pea color & pea texture, copy figure 14.8 from p.268 to follow along. If the 2 dominant alleles (yellow & round) were inherited together and the 2 recessive alleles were inherited together, then gametes of the F1 offspring could only ever be YR (dominant pair) or (yr) recessive pair and the results of an F2 generation would be 75% yellow/round & 25% green/wrinkled (3:1 ratio). However, his observed ratios for the experiment showed more variation (yellow/round, green/round, yellow/wrinkled & green/wrinkled). This was evidence that assortment between different traits is not dependent on one another. Draw figure 15.2 on p.287 linking these findings and meiosis. This diagram shows that at the end of meiosis 2, the gametes that result show all the possible combinations from the original F1 cell undergoing meiosis: The F1 cell starts out with YyRr, one of each allele variety for each trait, then metaphase 1 shows the 2 different ways the chromosomes can line up before separating. It is this random assortment pattern that allows 4 different but equally probable gametes to result. When performing any 2-trait cross, you must remember that it is the gametes of the parents that will generate the offspring and thus all the potential combinations for each parents' gametes must be determined first. This will be demonstrated in your genetics practice problems.

3.4 – What are some special scenarios with the law of dominance?

Some traits do not actually have a recessive form of a gene and both alleles are actually dominant. The first scenario is called **incomplete dominance**: 2 distinct phenotypes crossed form an intermediate phenotype. An example is red flowers crossed with white flowers produce all pink flower offspring. The second scenario is called **codominance**: 2 distinct phenotypes crossed form a phenotype showing both phenotypes. An example is A-B blood groups; the "A" allele produces one molecular ID tag and the "B" allele produces a different molecular ID tag. A person with AA blood only has "A" ID tags and BB blood types only have "B" ID tags. A person with AB blood has both "A" & "B" ID tags. These ID tags are actually sugars that identify your blood as "self" and not to be attacked by your immune system. If A

person with AA blood receives AB blood, their body will attack the donated AB blood, recognizing the "B" as foreign. O blood is actually the recessive blood type form and leads to no carbohydrate being expresses, essentially a "naked" blood cell. Without any ID tags on them to be identified, O blood can be received by any blood type. Because there are 3 alleles (A, B & O), this is also a special case known as **multiple alleles** meaning more than 2 alleles for a trait.

3.5 – What are some special scenarios of interactions with genes?

The ever famous topic of "Nature vs. Nurture" is applicable to many cases of genetics. Some phenotypes depend on their interactions with temperature, chemicals, and interactions with other genes. Many traits like skin color and eye color occur on a gradient because they are controlled by many different genes, called **polygenic inheritance**. Our nutrition plays a role in our height also, such as consuming more vitamin D & calcium leading to optimal bone growth and thus maximum length. Many species' genders are determined by the temperature at which the eggs are incubated like in most reptiles.

Section 4 – Complex Heredity Patterns

4.1 – How are sex-linked traits & autosomal traits inherited differently?

Most sexually-reproducing organisms have gender-determining chromosomes, commonly called the **sex-chromosomes**, and the remainder of the chromosomes are called **autosomes**. Even though the sex chromosomes determine gender, the X chromosome actually carries many genes for other traits as well. The Y chromosome carries so few non-gender based traits that we always assume a sex-linked trait is referring to a trait on the X-chromosome, and also call them **X-linked traits**. Most commonly females have two X chromosomes and a female's gender genotype would be XX, while males have one X and one Y chromosome and a male's gender genotype would be XY. If we only consider gender genes, then females are always and only homozygous (XX) and males are always and only heterozygous (XY). When we consider all the non-gender based X-linked genes however, these rules change. Because females have TWO X-chromosomes, they can have the typical homozygous dominant, homozygous recessive or heterozygous genotype. These genotypes are written as the letter X with a superscript representing the allele of interest. Examples are shown in figure15.7 on p.291.

4.2 – What is an example of X-linked inheritance?

For example normal vision is dominant to colorblindness and is an X-linked trait. A colorblind female would have the homozygous recessive genotype X^nX^n but a normal vision female could be homozygous dominant X^NX^N or a heterozygote called a **carrier**, X^NX^n. Males on the other hand can only be homozygous dominant X^NY or homozygous recessive X^nY, because they only have ONE "X" chromosome which the colorblind allele is found on. For this reason, males can never be heterozygous/carriers for an X-linked trait but females can be. A good rule to remember is that males always inherit their Y chromosome from their father only and their X chromosome is inherited from their mother only. This means the only way for a male to inherit an X-linked trait is from their mother. Females inherit one X chromosome from their mother and the other X chromosome from their father. This means a female will not show a **recessive** phenotype unless her father is also a **recessive** phenotype.

4.3 – When does the law of independent assortment not happen?

When 2 or more traits are on the same chromosome, they depend on each other to a degree based on their location on the chromosome. When crossing over happens during prophase 1 of meiosis, 2 genes may be so close together that they cross-over to their homologous chromosome together and so they do somewhat depend on each other. This phenomenon of when genes are located on the same chromosome is called **gene-linkage**.

If a homozygous dominant gray, normal winged fly is crossed with a homozygous recessive black, mutant winged fly, we expect all dominant phenotype (but heterozygous genotype) flies in the F1 generation assuming the law of independent assortment. If we then testcross an F1 fly, we would expect equal percentages of offspring having gray body/normal wings, black body/ mutant wings, gray body/mutant wings & black body/normal wings. Show this cross in your notes to see these expected results. Notice also that 50% of the offspring have phenotypes **exactly like one of the parents**, and the other 50% of the offspring have phenotypes that are a **mixture of the 2 parents**. Thomas Hunt Morgan did this experiment but the results turned out very different than expected.

4.4 –How did Morgan conclude genes can be linked?

Morgan's results yielded 83% had a phenotype exactly like one of the parents, and the other 17% had a phenotype that was a mix of the parents, showing that recombination of the parental alleles was not happening as expected. This led Morgan to believe some genes are linked together on the same chromosome and therefore will only assort independently from one another sometimes. Draw figure 15.10 on p.295 demonstrating Morgan's cross results. Notice that crossing-over does occur in the F1 dihybrid's egg cells and that she produces the expected 4 gamete combination types; however, the frequency that these 4 gamete types are seen does not match the expected frequency of 25% each. This is because the alleles for body color & wing type are very close together and therefore remain as a linked set of alleles a larger amount of times versus recombining independently with the alleles on the homologous chromosome.

4.5 – How can you tell if 2 genes are linked or on separate chromosomes?

One thing to notice from Morgan's experiment is that he only saw crossing-over data because he looked at 2 traits and at least one of the fly's genotypes was heterozygous. If both parents' genotypes are homozygous, you will never be able to tell any information about crossing over because the alleles are exactly the same so no recombining would be noticed anyway! Generally, if a 2-trait cross is presented to you, be aware it may involve **linked genes**.

The tell-tale sign of linked genes is that the **number or frequency of offspring with phenotypes matching one of the parents EXACTLY will be higher than the number or frequency of offspring with phenotypes that are a RECOMBINATION of the two parents**. From figure 15.10, notice that 965 flies have exactly the same phenotype as the female parent and 944 flies have exactly the same phenotype as the male parent. These combined equal 83% of the total offspring which is higher than the expected 50% **parental-type offspring**. The recombined offspring are only 17% of the total which is lower than the expected 50% **recombinant-type offspring**.

4.6 – Why do mitochondrial genes only come from the mother?

The final bizarre genetics pattern is with **mitochondrial genes**. When a sperm fertilizes an egg, it only provides its DNA. Just like transcription factors present in the mother's egg, all of the organelles are also present in the egg. This means that some traits that are only due to genes in the mitochondria can be inherited by all children but they only come from the mother.

Section 5 – Mathematical models of heredity

5.1 – How can we estimate the distance between linked genes?

Knowing that 2 genes are on the same chromosome brings up the question of how far apart they are. The formula used to calculate this is called the **recombination formula** and must be memorized as it is not on the formula sheet. Show all math for this formula using the testcross offspring on p. 295.

Recombination frequency = number of recombinant offspring / total offspring

Related to the recombination formula is **gene mapping**, where we can determine the relative distances among various genes on a chromosome, in units called **map units** (**mu**). Copy the model in figure 15.11 on p.296 showing how to do this.

5.2 – How can you solve multi-trait problems with Probability rules?

If you had a 5-trait cross such as AAbbCcddEe x aaBbccDDEe, the Punnett square for it would need a horrifying number of boxes. If we assume that each gene is on a separate chromosome (non-linked genes), we can assume they will all assort independently and we can simply calculate each trait's outcomes by itself and then combine all outcomes at the end. For example, if I asked what's the probability that the offspring would be recessive for the b trait, this requires both parent 1 **AND** parent 2 donate a recessive b allele. The first parent has a 2/2 chance of donating the b allele and the second parent has a ½ chance of donating the b allele. The word "**AND**" always means MULTIPLY probabilities. So the probability of a bb offspring = 2/2 x 1/2 =2/4 or **1/2**. If I asked what's the probability of being recessive for b or recessive for d, we first work each trait individually. The probability of bb is 2/4 and the probability of dd is 0/4 or just 0. The word **OR** always means ADD probabilities, so 2/4 + 0/4 = 2/4 or 1/2. What's the probability of being heterozygous or homozygous recessive for "E" and homozygous recessive for "C"? heterozygous Ee = 2/4 + homozygous recessive ee = 1/4 gives 3/4. Homozygous recessive cc = 2/4. Finally, multiply together 3/4 x 2/4 = 6/16 or 3/8.

5.3 – How is the chi square statistical test used in genetics?

The chi square test naturally suits genetics problems because we always have some expected results based on Punnett squares, probability rules, or recombination formulas. While the steps & calculations are too numerous to include here, you should note that when using a chi square:

- Expected values are those calculated based on the known/tested inheritance pattern.
- The actual numbers for expected values are calculated based on the data provided (observed data).
- The observed values are simply substituted into the chi square formula.

Section 6 – Human Disorders & Pedigrees

6.1 – How do Chromosomal Mutations Arise during Cell Division?

Errors during cell division occasionally happen and consequences vary. In **nondisjunction** chromosomes fail to separate for some reason during anaphase leading 1 cell to have too many chromosomes and 1 cell having too few chromosomes. Down syndrome is an example in which nondisjunction during meiosis 1 leads to some gametes having 22 chromosomes and some having 24 (instead of all having 23). If the gamete with 24 chromosomes combines with a normal 23 gamete, the result is a child with 47 chromosomes.

Most other chromosomal mutations happen during crossing over and have very negative impacts because they involve long sections of DNA carrying many genes. During crossing over sometimes sections of chromosomes undergo **deletions**, **duplications**, **inversions** (reversed), & **translocations** (swapping). Translocations between homologous chromosomes are beneficial but when occurring between non-homologous chromosomes, it usually has negative results. These chromosomal mutations are diagrammed in figure 15.14 on p.298. Chromosomal mutations are easy to visualize by making an image called a **karyotype** of the chromosomes in homologous pairs (p.250 & p.299).

6.2 – How can we trace genetic disorders in a family?

Genetic disorders are those that are caused by some DNA mutation that is present in a gamete that is passed to offspring. The majority of significant disorders are caused by recessive alleles on autosomes or X-chromosomes, but some are caused by dominant alleles. By using the rules of probability & heredity, it is possible to make a genetic family tree called a pedigree that maps out the inheritance of alleles within families. While these can be used to predict the likelihood of parents having children with disorders, they are just models and many other factors can influence genetic outcomes. Pedigrees will be seen & practiced in your genetics problem packet.

6.3 – How is an autosomal recessive disorder recognized on a pedigree?

Because recessive disorders require two recessive alleles, an affected individual is always assumed to have the homozygous recessive genotype. The parents of an affected individual can however both be physically unaffected but be carriers of the recessive allele (heterozygotes). So if an affected individual has unaffected parents, it is always a recessive disorder.

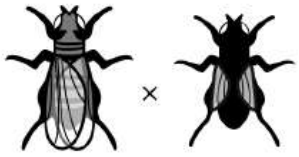
6.4 – What differentiates X-linked & autosomal recessive disorders?

Recall from X-linked disorders that boys only inherit the Y chromosome from their father and only the mother passes the boy's X chromosome to him. If an unaffected mother & father have children where only the sons are affected, it must be an X-linked recessive disorder carried by the mother. So the rule of thumb is that autosomal recessive disorders will affect males & females similarly but an X-linked recessive disorder will affect males more frequently.

6.5 – What differentiates X-linked & autosomal recessive disorders?

Dominant disorders usually show up in a higher frequency of individuals due to the law of dominance on phenotypes. Autosomal dominant disorders would affect males & females equally. In X-linked dominant disorders an affected father and an unaffected mother would only have affected daughters because the father's X chromosome only passes to his daughters.

1. You are studying the genetics of fruit flies, some further data is provided below:



BbVv
Wild-Type Female
(tan body, wild-type wings)

×

bbvv
Mutant Male
(black body, vestigial wings)

Genotypes	*BbVv* Tan, Wild Type	*bbvv* Black, Vestigial	*Bbvv* Tan, Vestigial	*bbVv* Black, Wild Type
Expected results	862	862	862	862
Observed phenotypes	1,447	1,416	309	277

In *Drosophila melanogaster* the allele for wild-type tan body color (*B*) is dominant to the recessive allele for black body color (*b*). Similarly, the allele for wild-type wing shape (*V*) is dominant to the recessive allele for vestigial wing phenotype (*v*). In the cross diagrammed above, the expected and observed results are shown. Which of the following best explains the observed results of the cross?

(A) The alleles for body color and wing shape assort independently, as predicted by Mendel's laws.
(B) The genes for body color and wing shape are located close to each other on the same chromosome.
(C) The traits of body color show complete dominance over the traits of wing shape.
(D) The observed variations in body color and wing shape are detectable in males but not in females.

2. At the 64 cell stage of embryo development, the next round of cell division has 1 cell undergo meiosis and the other 63 cells undergo mitosis. How many total cells would be present in the embryo after this round of cell division?
A) 130
B) 128
C) 127
D) 126

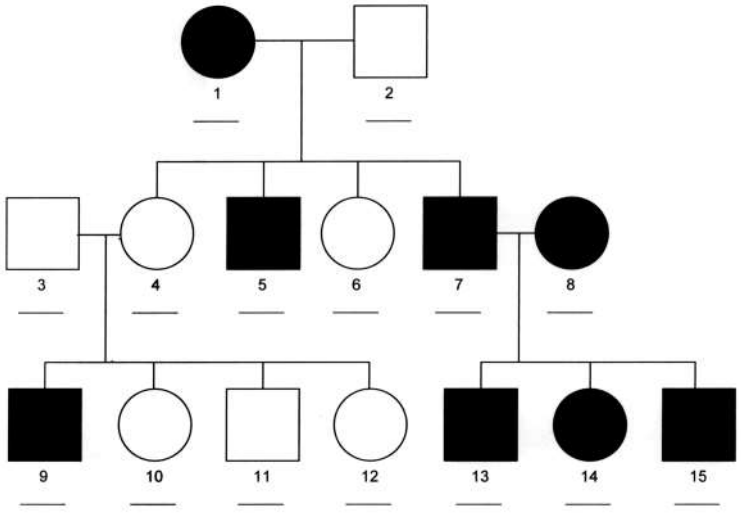
3. If the process of cellular respiration were disrupted, which of the events of the cell cycle would be the least affected?
A) Cytokinesis in plant cells
B) Anaphase in animal cells
C) The S Phase in fungi cells
D) Diffusion of CDK in animal cells

4. For a newly evolving eukaryote, what would be the advantage of using eukaryote-like cell division rather than binary fission like a prokaryote?
A) Binary fission would not allow the organism to have complex cells.
B) Cell division would allow for the orderly and efficient segregation of multiple linear chromosomes.
C) Cell division would be faster than binary fission.
D) Cell division allows for lower rates of error per chromosome replication.

5. Which of the following best describes cell cycle regulatory molecules?
A) CDK constantly fluctuates in concentration during interphase.
B) Cyclin concentrations increase as they enter M phase but decrease during interphase.
C) In the absence of cyclin, MPF could still trigger entry into the S phase.
D) The amounts of DNA & Cyclin follow the same pattern of concentrations during interphase.

6. The destruction of which cell structure would most directly affect cytokinesis in plants?
A) Nucleus
B) Golgi
C) Chloroplast
D) Vacuole

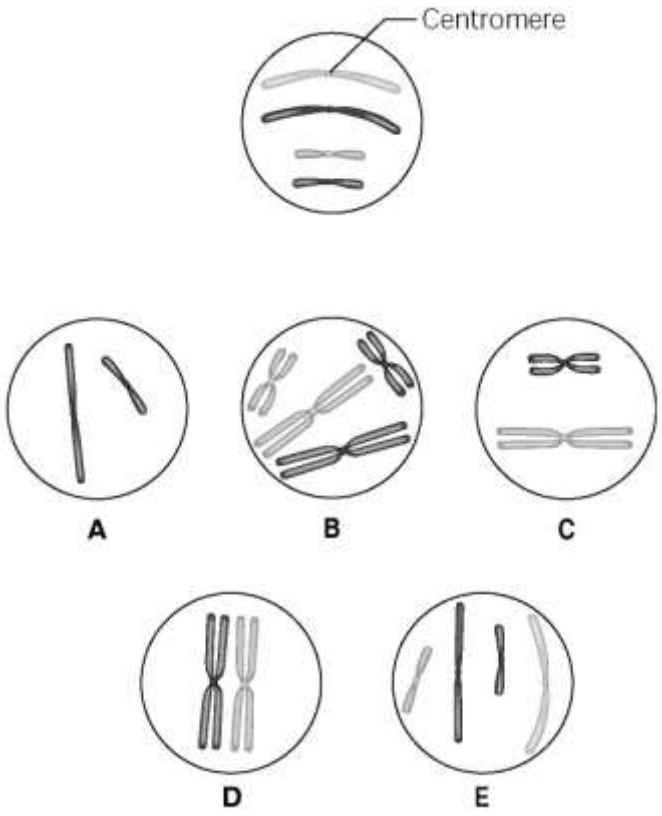
The pedigree below shows the inheritance patterns of a disorder. Circles represent females, squares are males. Black shading symbolizes an affected individual, unshaded symbolizes unaffected individuals.



7. Which statement is the most accurate?
A) Individual 14 will pass the disorder allele only to her male offspring.
B) Individual 9 received a disorder allele from their mother and the other from their father.
C) Individual 6 is a carrier of the disorder allele.
D) Individuals 10 & 12 must have the same genotype.

Use the following information to answer the questions below.

The lettered circles in the figures below show the nuclei of cells at various phases of cell division. The chromosomes in the unlettered circle represent DNA of a diploid cell that has not yet replicated. There are two pairs of homologous chromosomes, one long and the other short. One haploid set is symbolized as black and the other haploid set is gray.



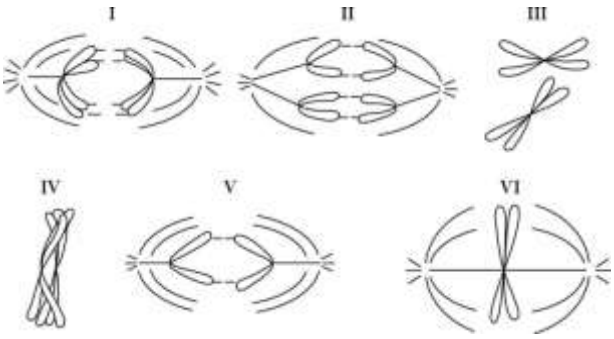
Use the letters above as answer choices. If more than one letter choice is correct, bubble in all correct letter choices.

8. What is/are the correct chromosomal condition for one daughter nucleus after telophase of mitosis?

9. Which nuclei is/are the result of a mutation which may be fatal?

10. In which nuclei would crossing over most likely occur?

Refer to the drawings below of a single pair of homologous chromosomes as they might appear during various stages of either mitosis or meiosis, and answer question 9.



11. Which diagram(s) represent anaphase II of meiosis?
A) II only
B) III only
C) IV only
D) V only
E) either II or V

12. 4 Genes, ABCD, control 4 different traits in an organism. For the cross below, what is the probability that the offspring will be homozygous recessive for all 4 traits?

AaBbccdd x AabbCcdd

A) 1/2
B) 1/4
C) 1/8
D) 1/16
E) 1/32

Radish flowers may be red, pink, or white. A cross between a red-flowered plant and a white-flowered plant yields all-pink offspring.

13. The flower color trait in radishes is an example of which of the following?
A) incomplete dominance
B) sex linkage
C) codominance
D) a multiple allelic system
E) gene linkage

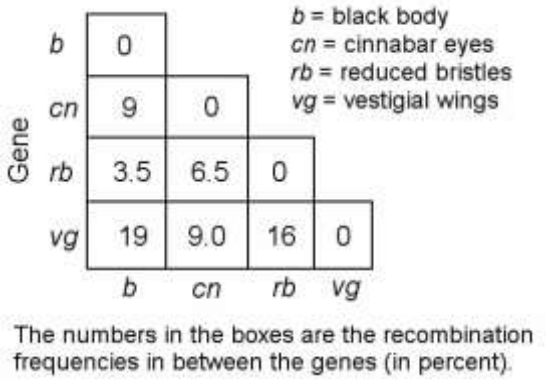


Figure 15.2

14. In a series of mapping experiments, the recombination frequencies for four different linked genes of *Drosophila* were determined as shown in Figure 15.2. What is the order of these genes on a chromosome map?

A) *rb-cn-vg-b*
B) *vg-b-rb-cn*
C) *cn-rb-b-vg*
D) *b-rb-cn-vg*
E) *vg-cn-b-rb*

15.

A new mutation that arose in one copy of gene *X* in a somatic cell resulted in the formation of a tumor. Which of the following pieces of evidence best describes how the new mutation directly caused the tumor?

(A) Protein X normally stimulates cell division, and the mutation created an overactive version of protein X.
(B) Protein X normally activates a growth hormone receptor, and the mutation decreased the stability of protein X.
(C) Protein X normally prevents passage through the cell cycle, and the mutation created an overactive version of protein X.
(D) Protein X normally regulates gene expression, and the mutation created an underactive version of protein X that blocked the cell cycle.

16.

If chemical signals in the cytoplasm control the progression of a cell to the M phase of the cell cycle, then fusion of a cell in G_1 with a cell in early M phase would most likely result in the

(A) replication of chromosomes only in the G_1 cell
(B) exiting of both cells from the cell cycle and into the G_0 phase
(C) condensation of chromatin in preparation of nuclear division in both cells
(D) transfer of organelles from the G_1 cell to the cell in the M phase

17.

A student in a biology class crossed a male *Drosophila melanogaster* having a gray body and long wings with a female *D. melanogaster* having a black body and apterous wings. The following distribution of traits was observed in the offspring.

Phenotype	Number of Offspring
Gray body, long wings	42
Black body, apterous wings	41
Gray body, apterous wings	9
Black body, long wings	8

Which of the following is supported by the data?

(A) The alleles for gray body and long wings are dominant.
(B) The alleles for gray body and long wings are recessive.
(C) Genes for the two traits are located on two different chromosomes, and independent assortment occurred.
(D) Genes for the two traits are located close together on the same chromosome, and crossing over occurred between the two gene loci.

18.

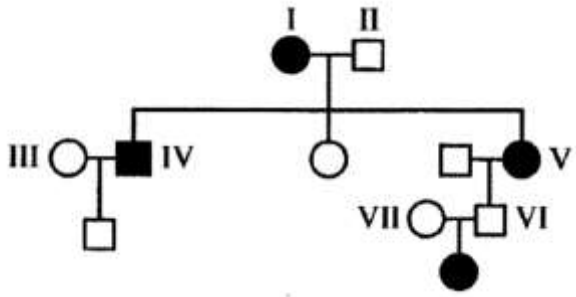


Figure 1. Pedigree of a family with affected individuals. Squares represent males, circles represent females, shaded symbols represent individuals with sickle-cell disease.

Possessing a single copy of the *HbS* allele has been shown to provide some resistance to infection by *Plasmodium falciparum*, the parasite that causes malaria. Which of the following individuals represented in the pedigree would have the greatest selective advantage in an area where malaria is common?

(A) I
(B) II
(C) III
(D) V

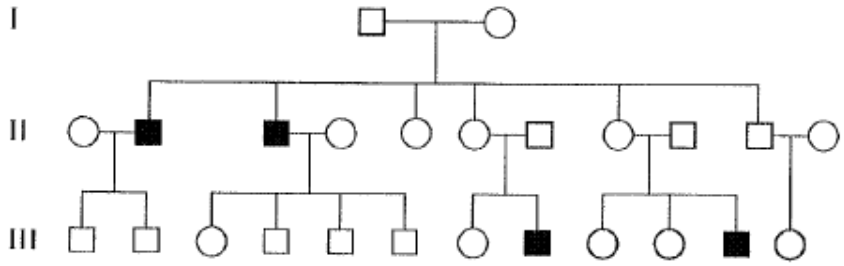
19.

A researcher examining a root tip observes a plant cell with condensed sister chromatids, kinetochores with attached microtubules, and individual chromosomes that are aligned at the equatorial plate of the cell. Which of the following best describes what the next process will be in the cell?

(A) Homologous chromosomes (each with two sister chromatids) will move toward opposite poles of the cell.
(B) Paired chromatids will separate, and the new daughter chromosomes will move toward opposite poles of the cell.
(C) The nuclear envelope will break down, and the spindle will begin to form.
(D) The chromatin will decondense, and the daughter cell will enter interphase.

20.

In the following human pedigree, squares represent males, circles represent females, and shaded symbols indicate individuals affected with a disorder.



One of the affected males from the third generation has a child with a female who is a carrier. For the pedigree shown above, which of the following best expresses the probability that the couple's first son will be affected with the disorder?

(A) 25%
(B) 50%
(C) 75%
(D) 100%

Table I shows the results of breeding experiments to examine the inheritance of flower color (purple versus white) and pod shape (inflated versus constricted). For the crosses recorded in Table I, true-breeding parents were crossed to produce F_1 offspring, which were then testcrossed to homozygous recessive individuals. Table II shows the results of computer-simulated crosses to model the inheritance of leaf shape (broad versus narrow) and flower color (purple versus white).

TABLE I: RESULTS FROM CROSSES WITH PEA PLANTS

Parental Cross	Phenotypes of F_1 Offspring	Phenotypes of Testcross Offspring (numbers of individuals)			
Purple × White	Purple	Purple (461)		White (468)	
Inflated × Constricted	Inflated	Inflated (593)		Constricted (588)	
Purple, Inflated × White, Constricted	Purple, Inflated	Purple, Inflated (315)	Purple, Constricted (312)	White, Inflated (320)	White, Constricted (317)

TABLE II: RESULTS OF COMPUTER-SIMULATED CROSSES

Parental Cross	Phenotypes of F_1 Offspring	Phenotypes of Testcross Offspring (numbers of individuals)			
Broad × Narrow	Broad	Broad (4870)		Narrow (4862)	
Purple × White	Purple	Purple (4253)		White (4259)	
Broad, White × Narrow, Purple	Broad, Purple	Broad, White (672)	Broad, Purple (75)	Narrow, White (61)	Narrow, Purple (664)

Use the information above to answer the questions on the following page.

21. Based on the data in Table I, which of the following best explains why there are no individuals with constricted pods in the F_1 generation?

(A) Inflated pod shape is dominant to constricted pod shape.
(B) The inflated-pod offspring in the F_1 generation are homozygous.
(C) Constricted pod shape typically arises from a new mutation in the F_1 generation.
(D) The constricted-pod offspring are carriers for the inflated pod shape allele.

22. In Table I, the ratio of phenotypes in the offspring from the testcross with F_1 plants that had purple flowers and inflated pods suggests that the genes for flower color and pod shape are located

(A) close together on the same autosome
(B) on the X chromosome
(C) on different chromosomes
(D) on a mitochondrial chromosome

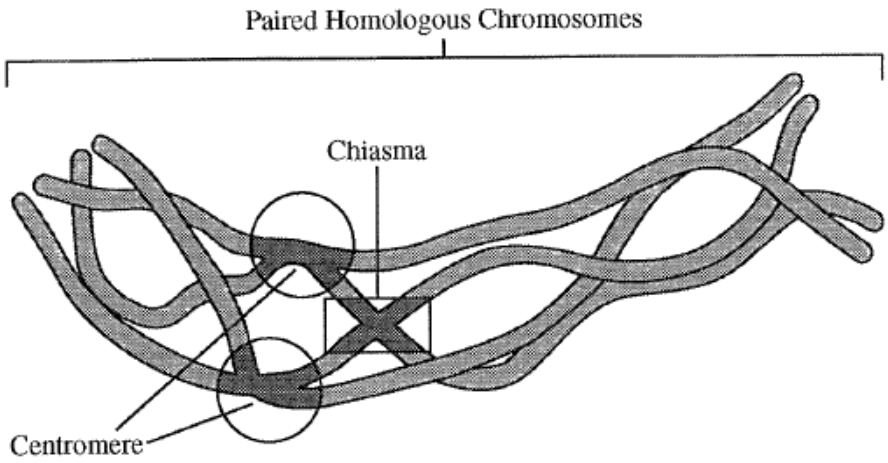
23. Which of the following provides the best justification for an assumption that might have been used in the computer simulation (Table II) ?

(A) The broad allele is recessive to the narrow allele because broad leaves appear in every generation.
(B) The purple allele is dominant to the white allele because all the offspring from the cross of purple-flowered and white-flowered plants had purple flowers.
(C) The narrow allele is codominant with the purple allele because the purple-flower trait and the narrow-leaf trait segregate together.
(D) The white allele is dominant to both the broad and narrow alleles because plants with either type of leaf shape can have white flowers.

24. In Table II, the F_1 offspring of the cross between broad-leaved, white-flowered plants with narrow-leaved, purple-flowered plants have a phenotype that differs from that of either parent. However, many testcross offspring have the same phenotype as one of the two plants in the parental cross, but relatively few testcross offspring have the same phenotype as the F_1 offspring. Which of the following best explains the observation?

(A) Recombination between the leaf-shape and flower-color genes resulted in chromosomes carrying a dominant allele of both genes.
21. (B) Recombination between the broad and narrow alleles of the leaf-shape gene resulted in chromosomes carrying three different alleles at the same genetic locus.
(C) Independent assortment of homologous chromosomes resulted in the combinations of alleles present in the parental generation.
(D) The computer model cannot capture the possible assortments of gametes when multiple genes are considered.

24.



The process depicted in the image above is best summarized by which of the following descriptions?

(A) During the synthesis phase of the cell cycle, DNA molecules replicate to generate identical daughter cells.
(B) Centromeres align specific gene sequences of homologous chromosomes during mitotic divisions.
(C) The spindle apparatus attaches at chiasma during metaphase of mitosis.
(D) During meiosis, crossing over leads to recombination of alleles between homologous chromosomes.

25.

A certain species of plant has four unlinked genetic loci, *W, X, Y,* and *Z*. Each genetic locus has one dominant allele and one recessive allele. For a plant with the genotype *WwXxYyZz*, what is the probability that the plant will produce a gamete with a haploid genotype of *Wxyz* ? Give your answer as a fraction or as a value between 0 and 1, to four decimal places.

FRQ Practice

1.
A geneticist is investigating the inheritance of genes for bitter taste and hard rind in watermelons. Soft rind is recessive and causes the rind to absorb too much water during growth. Sweet watermelons are also a recessive trait causing the watermelons to store large amounts of sucrose and be very sweet. The geneticist wishes to determine if the genes assort independently. She performs a testcross between a bitter/hard rind hybrid and a plant homozygous recessive for both traits. The following offspring are produced:

bitter/hard-rind – 88	sweet/soft-rind – 81
bitter/soft-rind – 68	sweet/hard-rind – 62

All work must be shown to receive credit.

a. **State** the most appropriate null hypothesis for this data.

b. **Calculate** the chi-square value for your null hypothesis. Give your answer to the nearest hundredth.

c. **Explain** whether to accept or reject the null hypothesis

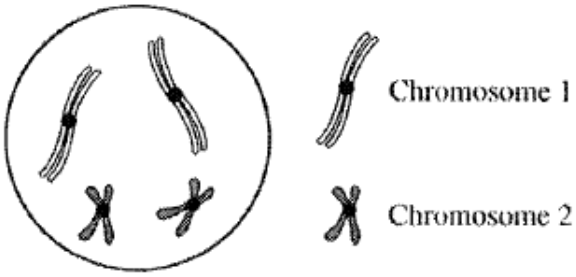
d. Regardless of your hypothesis decision, assume that the 2 traits are linked on the same chromosome. **Calculate** the number of map units the 2 genes are located from each other on the chromosome.

2.
Both mitosis and meiosis are forms of cell division that produce daughter cells containing genetic information from the parent cell.

a. Describe **TWO** events that are common to both mitosis and meiosis that ensure the resulting daughter cells inherit the appropriate number of chromosomes.

b. The genetic composition of daughter cells produced by mitosis differs from that of the daughter cells produced by meiosis. Describe **TWO** features of the cell division processes that lead to these differences.

3.

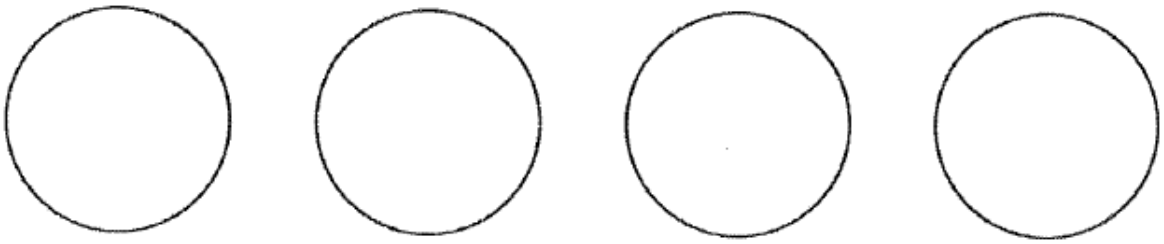


In a certain species of plant, the diploid number of chromosomes is 4 (2n = 4). Flower color is controlled by a single gene in which the green allele (*G*) is dominant to the purple allele (*g*). Plant height is controlled by a different gene in which the dwarf allele (*D*) is dominant to the tall allele (*d*). Individuals of the parental (P) generation with the genotypes *GGDD* and *ggdd* were crossed to produce F_1 progeny.

(a) **Construct** a diagram below to depict the four possible normal products of meiosis that would be produced by the F_1 progeny. Show the chromosomes and the allele(s) they carry. Assume the genes are located on different chromosomes and the gene for flower color is on chromosome 1.

(b) **Predict** the possible phenotypes and their ratios in the offspring of a testcross between an F_1 individual and a *ggdd* individual.

(c) If the two genes were genetically linked, **describe** how the proportions of phenotypes of the resulting offspring would most likely differ from those of the testcross between an F_1 individual and a *ggdd* individual.



4. Draw a diagram of a mitotic cell cycle including the following:

a. The three stages of Interphase identified & labeled.
b. The M phase identified & labeled.
c. Two cell cycle checkpoints identified & labeled.
d. Identify & label where MPF would be at a high concentration.
e. Identify & label where cyclin would be at a high concentration.
f. Identify & label where chromosomes become pairs of chromatids.